Precessing Gamma Jets in extended and evaporating Galactic Halo as source of GRB

Daniele Fargion* , Andrea Salis

Physics Dept. Rome University "La Sapienza"
P.le A.Moro 00187
**INFN sez. Roma1 Univ."La Sapienza", Rome*

The Precessing Gamma Jets (GJ) in binary systems located in extended or evaporating galactic halo should be the source of GRB. The GJ are born by Inverse Compton Scattering (ICS) of thermal photons (optical, infrared,...) onto (power law) electron jets (from GeV energies and above) produced by spinning pulsars or black holes. The thermal photons are emitted by the binary companion (or by their nearby accreting disk). The collimated GJ beam is trembling with the characteristic pulsar millisecond period and it is bent by the companion magnetic field interactions, as a lighthouse, in a nearly conical shape within the characteristic Keplerian period; an additional nutation due to the asymmetric inertial momentum may lead, in general, to aperiodic behaviour of GRB signals. SGRs are GRBs seen at the periphery of the hard energy GJ beam core. The original birth locations of GJ (SNRs, planetary nebulae, globular clusters,...) are smeared out by the high escape velocity of the system; the Neutron Star (NS) high velocity is possibly due to the asymmetric jet precession , and consequent "rowing" acceleration, related to the eccentricity of the binary system. The GJ power is, for realistic parameters, comparable to the one needed for GRB in extended or evaporating galactic halo. Their detailed spectra and time evolution fit the observed data. The expected GRB source number (within present BATSE sensitivity) is tens of thousands, compatible with the allowed presence of $10-20\%$ GRB repeaters.

The Eddington luminosity and the opacity in GRBs are the cornerstones in understanding, constraining and finally building in a chain of arguments any realistic GRB model. Spherically symmetric GRBs, either in extended galactic halo or at the cosmological edges, overcome Eddington luminosity (because of the millisecond times and the hundred Kms spaces of GRB structure). The consequent explosive fireball models imply a copious electron pairs production (by $\gamma-\gamma$ scattering), huge opacity and a consequent photon ther-

malization (via electron pairs) which is in disagreement with the observed non thermal GRB spectra. This over Eddington luminosity (and opacity) problem is present also for the SGRs as isotropic sources. In this framework it is not possible to solve the problem by splitting or hiding the GRBs nature from the SGRs one; on the contrary this "discriminatory" attitude just doubles and deepens the puzzle. Moreover the unique gamma event, the 5/3/79 GRB [1] its earliest hard spectra nature implies and calls for a strong link between SGRs and GRBs. Consequently the SGR locations suggest a "local" (extended galactic halo, local group) site for GRBs. Therefore the main steps toward the GRB model are: 1) the fireball (isotropic) GRB sources (galactic or cosmological) are thermal sources; we need a non thermal one and we consider a non equilibrium gamma (anisotropic) *beamed source*. 2) The high p-p scattering as gamma source leads to characteristic pion mass energy spectra absent in GRB spectral breaks, lines or other features. Moreover these scattering exhibits a poor beaming efficiency ($\theta_\gamma \simeq \theta_{\pi^o} \simeq \sqrt{\frac{m_p}{E_p}}$) and lower flux amplification compared, for example, to the Inverse Compton Scattering (ICS) by electrons at same energy ($\theta_\gamma \simeq \theta_e \simeq \frac{m_e}{E_e}$). 3) Electron-positron pair annihilation (and their generation) should be traced by characteristic gamma lines (even smeared by Doppler shift) nearly absent in most known GRB spectra. 4) Synchrotron radiation at MeV leads to spectra in disagreement with data and it calls for unbelievable huge magnetic fields and/or cosmic electron energies as well as long collimation lenght. 5) Bremsstrahlung radiation as above is also in disagreement with observational GRB data (no beaming and consequent thermalization). 6) We were forced to consider the best physical process for beaming GRB [2]: the ICS of ultrarelativistic electrons onto thermal photons (we neglected the ICS contribute by protons because of their severe suppression factor in the corresponding Thomson cross section: $((\frac{m_p}{m_e})^2)$. 7) Because of the primary cosmic rays electron spectrum near the Earth we considered the energy composition of the electrons near the maximum at GeV as the electron beam characteristic energy in jets. 8) In this way we assumed that the same GeV electron jets are responsible for a large fraction of primary cosmic rays. The jet number is therefore bounded by the total cosmic rays electrons flux data. These anisotropic beams of c.r. electrons are now observed isotropically because of the presence of randomizing and smoothing interstellar magnetic fields. 9) The absence of any detectable anisotropy for c.r. electrons at GeV also implies a limited ($<$ yrs or tens of yrs) collimated lenght of the electron jets. 10) Relativistic kinematics of ICS leads, for any large c.r. electrons γ Lorentz factor, to a corresponding small beam angle θ_e for the ICS gamma rays favouring the existence of an associate collimated gamma beam or GJ. The characteristic Lorentz factor, the consequent gamma beam collimation and the average gamma energies are

$$\gamma_e = 2 \cdot 10^3 \Big(\frac{E_e}{GeV}\Big); \quad \theta_e = 5 \cdot 10^{-4} \Big(\frac{E_e}{GeV}\Big)^{-1};$$

$$\overline{h\nu_\gamma} = 1.38\Big(\frac{\gamma_e}{2\cdot 10^3}\Big)^2\Big(\frac{T}{6000\ K}\Big)MeV \tag{1}$$

in rough agreement with the needed energies in GRBs. Here E_e is the electron energy in the jet while T is the thermal temperature of the nearby companion star. 11) The existence of collimated blazar-like jets of particles is not new in astrophysics and it is known since long time in extragalactic high energy astrophysics (superluminal objects, quasars, etc.); their ICS, for instance onto cosmological BBR or self ICS on synchrotron radiation, may be the source of variable highest gamma rays as MRK 421. However the same extragalactic AGNs or quasars are not suitable GRB candidates because of their too large masses and because of the associated too long Schwartzchild time scales $\frac{r_s}{c} \sim 10^3\Big(\frac{M}{10^8 M_\odot}\Big)s$, *i.e.* million times longer respect to the characteristic millisecond GRB time structures. 12) This millisecond trembling (or hundredth, tenth of second) of GRBs calls, let say better *cries*, desperately for the pulsar-like (NS or BH) nature of the GRB sources. Indeed the (nearly) absence of submillisecond structure (if not a misleading coincidence of a perverse Nature...) is in full resonance with the lower known bounds on pulsar period at half millisecond. 13) Therefore we are forced [2] to assume as candidate sources of GRB compact fast spinning NS (or BH) which eject electrons (as well protons) at GeV energies (NSJ) and which also eject, by ICS, an associated gamma jet. The simplest hypothesis, ICS onto 2.73 K BBR, leads to a quite unefficient electron jet $\rightarrow$ GJ energy conversion in disagreement with needed intensities in GRBs. 14) Therefore, in order to enhance and amplify the ICS efficiency to the needed ones, we are driven to assume a nearby "lamp", *i.e.* a nearby copious stellar photon source as a binary companion. 15) The binary companion plays also a key role in deflecting and in precessing and possibly powering the jet leading to dynamical "blazing" or "lighthouse" beaming which explains the transient "explosive" nature of the GRBs. 16) Therefore the ICS onto thermal photons gives life to a *collinear* GJ along with the NSJ. We remind that these NSJ or GJ are in general symmetric (up-down) jets. Moreover, as we show elsewhere [3], the internal angular structure of the GJ (by relativistic kinematics) allows the understanding of the time-energy evolution (soft-hard-soft) of GRB spectra during the sweeping of the precessing GJ. 17) The compact object, source of the jet, NSJ, of a mass M_c, in the Keplerian system, with a solar-like companion of mass M_s, precedes because of its dipolar magnetic interaction with the companion field. 18) The symmetric (up-down) rotating GJ sprays in a conical shape as a lighthouse in the dark spaces. It becomes observable (as just a laser light in a night club) either if a large gas or dust volume (or a shell screen) diffuses or reflects it, or if the observer enters inside the beam core. Recent astrophysical candidates in such configurations have been revealed: the last observed twin diffused cones in Egg Nebula (CRL 2688), the twin rings in SN1987A and in Hourglass Nebula projected on their red giant relic shells. 19) The Keplerian angular velocity ω_b must be derived by the characteristic θ_e beam angle and

by the GRB duration lenght $\Delta\tau_b$; therefore it also underlines a characteristic consequent binary distance r_b:

$$\omega_b \approx \frac{\theta_e}{\Delta\tau_b} \approx 2 \cdot 10^{-4} \Big(\frac{\gamma_e}{2 \cdot 10^3} \; \frac{\Delta\tau_b}{2s} \Big)^{-1} s^{-1} \tag{2}$$

$$r_b \approx 2.5c \Big[\Big(\frac{M_c}{M_\odot} \Big) + \Big(\frac{M_s}{M_\odot} \Big) \Big]^{1/3} \cdot \Big(\frac{\gamma_e}{2 \cdot 10^3} \; \frac{\Delta\tau_b}{2s} \Big)^{2/3} s \quad . \tag{3}$$

20) These distances are characteristic of the Roche capture lobes of stellar sizes; so one must expect that these configurations lead to a feeding processes (accretion disk) and to a "strip tease" of the companion as well as to a merging of the companion onto the NSJ. 21) During that merging ($\Delta\tau \sim 2s$, $r_b \sim 2s$) an obscured (opaque) configuration would result and GRBs in those parameter window might be suppressed. 21) Indeed the characteristic GRB duration $\Delta\tau_b \sim 2s$ exhibits an absence or a lack of sources: the transient opacity at that stages may be the cause of it. 22) The consequent new configurations (smaller $\Delta\tau_b < 2s$ durations) which may arise in more bound systems are associated to smaller size white dwarf (or even NS) companions; the last stages may be compact and faster relic accreting disk (or ring) whose thermal photons are interacting (by ICS) onto the NSJ. 23) These more stable configurations might be associated to type II GRBs whose shorter durations, harder spectra are related to the higher Lorentz factors and the consequent more beamed jets. 24) The last oldest stable GJ may lead to periodic configurations and they may be identified with known gamma ray repeaters or even to gamma ray pulsars [2]. Recent evidence for such a strong link between SGRs and gamma ray (or hard X ray) pulsars are offered by the last discover [4] and the step by step (soft gamma ray burst $\rightarrow$ gamma pulsar) understanding of identified GROJ1744-28 pulsar, near the Galactic Center. Its luminosity nearly above the Eddington one implies a beaming (even if not as collimated and energetic as harder gamma ray pulsars or SGRs or GRBs). Indeed this last X pulsar is shining at peak luminosity ten times above Eddington critical luminosity for a solar mass $L_{cr} \sim 1.3 \cdot 10^{38} \Big(\frac{M}{M_\odot} \Big) erg \; s^{-1}$; moreover its spinning down power $\dot{E}_s = -4\pi^2 I \frac{\dot{P}}{P^3} \sim 2.8 \cdot 10^{36} erg \; s^{-1}$ is nearly three order of magnitude <u>*below*</u> the observed peak or average luminosity $(3.5 \; or \; 1) \cdot 10^{39} erg \; s^{-1}$, calling for an "exceptional" (the largest ever observed) conversion efficiency from rotational energy into X burst. This over luminosity may be explained, within our model of a binary GJ with stellar companion, assuming an emission jet nature of the pulsar whose beaming amplifies the nominal luminosity by a θ_b^{-2} factor. Moreover the orbital binary parameters just discovered for GROJ1744-28 (Roche lobe radious size $\sim 8s \cdot c$) are well consistent with our model. 25) On the other extreme slow and wide binary systems are less powered (by accretion) and their jet energy is wider and it is therefore less observable (type I GRBs with longest burst duration). 26) As it will be shown in detail in the

next article [3], because of the concentric cone energy distribution (soft-hard) of the beam by ICS, the SGRs might be due to the more probable observations of the peripheric (and softer) zones of those cone beams, while the most rare observation of the beam core (where the hardest component of the ICS spectra is hidden) leads to the rarest, hardest and powerful GRB event. Therefore too far away GRB sources cannot be seen at their "SGR stage" because of the BATSE sensitivity threshold. 27) For a quantitative evaluation of the model one easely derives [2] the NSJ electron power $\dot{E}_j$ conversion (by ICS) into the beamed GJ one $\dot{E}_\gamma$

$$\frac{dE_\gamma}{dt} \approx 5 \cdot 10^{41} \Big(\frac{\gamma_e}{2 \cdot 10^3}\Big)^3 \Big(\frac{T}{6000K}\Big)^4 \Big(\frac{r_b}{2.5s \cdot c}\Big)^{-1} \Big(\frac{\dot{E}_j}{10^{38} ergs^{-1}}\Big) \Big(\frac{r_s}{R_\odot}\Big)^2 ergs^{-1} \tag{4}$$

where r_b is the binary distance of eq.3, T and r_s are the companion star temperature and radius, γ_e is the Lorentz factor of eq.1. 28) The assumed $\dot{E}_j$ power is a characteristic calibrating one for known galactic jets as Great Annihilator or SS433; one or even two order of magnitude are uncertain and they may be freely scaled on the $\dot{E}_j$ powers. Indeed these GJ power are characteristic of GRB in extended ($\sim 100Kpc$) or giant evaporating ($\sim 500Kpc$) volumes (or even within local group volumes). These huge volumes satisfy the observed GRB isotropy and the "edge" inhomogeneity. 29) The merging with Andromeda halo must and might be observed in a near future by some kind of anisotropy in GRB distribution at lowest fluxes. More details on the GRB model, spectra, applications and observational evidences are shown in ref.[3]; our model gives spectra able to successfully fit observed GRB ones and their "thermal evolution" contrary to quasi thermal fireball spectrum. Finally the relic c.r. electrons by NSJ are possibly related to the last COMPTEL evidence for a diffused relic extended (∼30 Kpc) halo. A consequence of the model is the presence, at huge distances, of NSJ barionic relic within an extended dark matter halo.

REFERENCES

1. E.E.Fenimore et al., Preprint LAUE-95-1220, Ap.J. March 96 (in press) .
2. D.Fargion, "The dark side of the Universe", World Scientific press 1994 p.88-99; D.Fargion and A.Salis, Astrophysics and Space Science **231**, 191 (1995) and references therein.
3. D.Fargion and A.Salis, preprint INFN n.1135 23-2-96, in Proc. Huntsville3.
4. C.Kouveliotou et al., Nature **379**, 799 (1996).